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THE EFFECTS OF CHROMIUM CONCENTRATION ON MAGNETICALLY POLARIZED HEAT-TREATED STEEL TORQUE TRANSDUCER SHAFTS

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In many applications where a standard sensory torque transducer ring would be impractical, two distinct portions of a hollow ferromagnetic high-speed steel shaft can be utilized as the torque transducer, in which a high degree of oppositely polarized circumferential magnetic domain alignment can be maintained, provided the steel has high coercive forces and is not too brittle. In this work, we have discovered that a large enhancement in transducer sensitivity can be gained by increasing the chromium concentration of the steel to as high as the 12% level (with nickel concentrations under l%), without the sacrifice of any essential mechanical properties. Beyond this optimal concentration level, the enhancement in the sensitivity appears to have saturated and then gradually disappears as additional chromium is added. Among the steel shafts we investigated were four with respective chromium concentrations of 0.15%, 3.5%, 12.0%, and 25.5%, that are correspondingly known as steel types W-1, S-7, D-2, and F-255. Their transducer sensitivities were found as 1.5, 4.0, 12.5, and 2.9 mG/N-m, respectively. Additionally, the S-7 and D-2 magnetic transducers exhibited still further increases in their sensitivity following their standard heat treatments, with the greatest increase of all occurring for the D-2 sample, which also had the highest sensitivity and the best linearity over the normal response range of any of the magnetic transducers studied. Corresponding to this sensitivity enhancement, we also found that the area of the axial hysteresis curves for the first three of these steels dramatically decreased as the chromium concentration went up to the 12% level, and then gradually increased again as additional chromium was added. However, relatively little change was observed in the already broad circumferential hysteresis curves over the range of chromium concentrations investigated, which assures that transducer integrity can be easily maintained throughout.